the VOLPE center

National PNT Architecture Workshop at Volpe

26 April 2007

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Agenda

- Welcome and Introductions
- Background of National PNT Architecture Effort
- National PNT Architecture Development Process
  - Data Gathering
  - Concept Development
  - Analysis and Assessment
- Overview of Current Status and Future Direction
- Interactive Session
  - Architecture-Level Questions
  - Identified PNT Gaps for 2025
  - Technologies and Concepts

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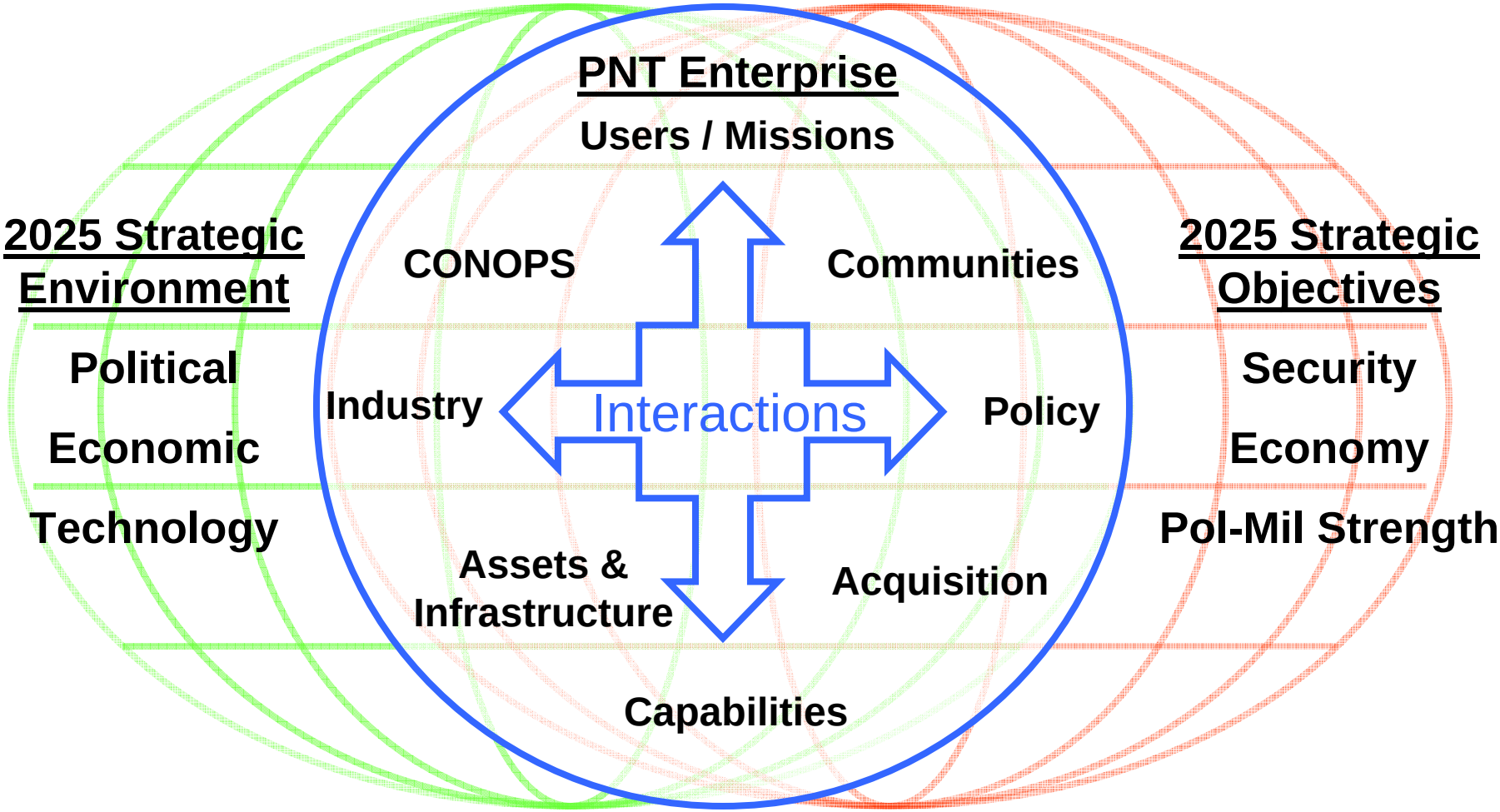
PNT Architecture Background

- Study requested by
  - Assistant Secretary of Defense for Networks and Information Integration
  - Undersecretary of the Department of Transportation for Policy
  - National Space-based PNT Executive Committee
- Justification
  - PNT Strategic Landscape is Changing
- Products
  - 20 year strategic outlook to guide near and mid-term decisions on PNT capabilities

National PNT Architecture Perspective



Enterprise Level Assessment to Ensure National PNT Preeminence
Cross Community Forum to Achieve Common Understanding

National PNT Architecture Scope

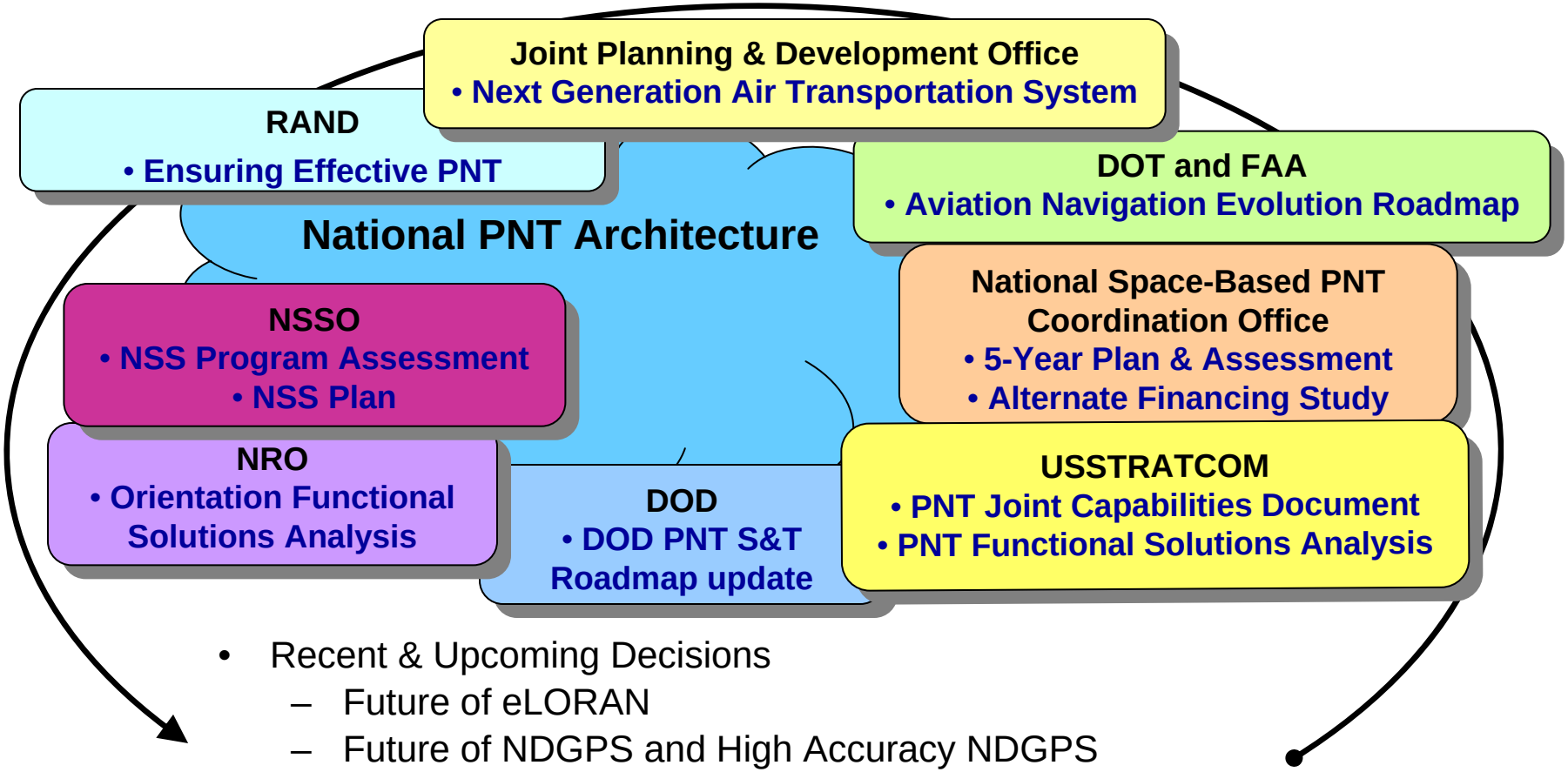
USERS	DOMAIN	MISSIONS	SOURCES	PROVIDERS
Military	Far Space	Space Nav	GNSS	Military
Homeland Security	Near Space	Terrestrial Nav	GNSS Augmentation	Civil
Civil	Atmosphere	ISR / Targeting	Terrestrial NAVAIDS	Commercial
Commercial	Surface	Traffic Management	Onboard / User Equip	International
Individual	Urban	Logistics	Networks	
	Enclosed	Manufacturing		
	Under Surface	Agriculture		
		Cooperative Location		
		Geo Science		
		Timing		
		Security		
		Orientation		

Broad Scope Requires Innovative Approaches and Focused Analysis Efforts

PNT Architecture Stakeholders

- National Security Space Office
- Dept of Defense / Networks and Information Integration
- Dept of Transportation / RITA
- Dept of Commerce
- Dept of Homeland Security
- Dept of State
- NASA
- National Space-Based PNT Coordination Office
- Dept of Transportation / FAA
- Dept of Transportation / FHWA
- Dept of Transportation / FRA
- Department of Interior / USGS
- National Security Agency
- National Geospatial Intelligence Agency
- US Army
- US Navy
- US Air Force
- US Marine Corp
- US Coast Guard
- US Strategic Command
- Joint Staff
- Air Force Space Command
- GPS Wing
- Dept of Defense / S&T
- US Naval Observatory
- National Institute for Standards and Technology
- Joint Planning Development Office
- Policy Board on Federal Aviation

Related Efforts & Upcoming Decisions



- Recent & Upcoming Decisions
  - Future of eLORAN
  - Future of NDGPS and High Accuracy NDGPS
  - Backup SATNAV Tasking
  - Backup PNT Needs (ADS-B, NGATS, Timing Infrastructure)
  - GPS III and OCX Acquisition Strategies

MAINTAIN SHARED SITUATIONAL AWARENESS

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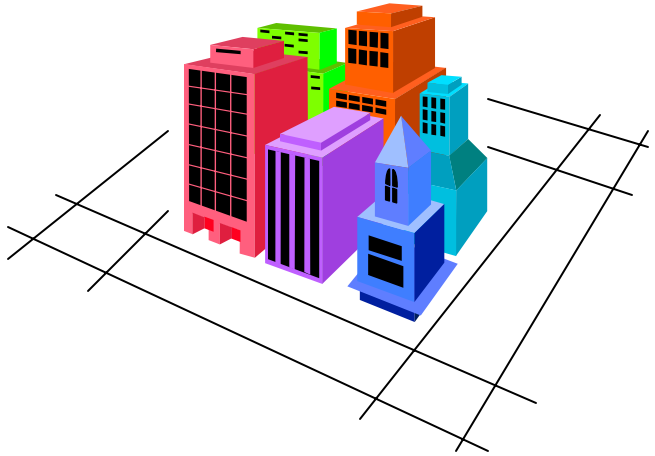
Purpose of NSSO Architectures

- Enterprise Level Guidance
  - High Level Capabilities
  - Fundamental Processes
  - Organizations
  - Infrastructure
- Similar to City Planning
  - Considerations for how people, buildings, transportation, utilities work together
  - Effect of External Factors (e.g., weather, state jurisdiction, etc.)
  - Objective is not to design all the buildings
  - May conduct detailed design of some elements, primarily to gain understanding of higher level issues



Architecting Process Overview

Potential Future Needs

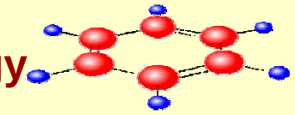
Current Reqmts
Future Needs

What do we need to do?

Operational Concepts

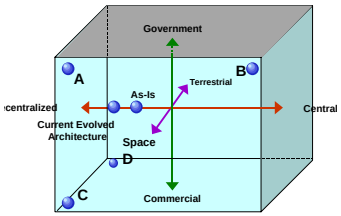
How do we want to do it?

Technology



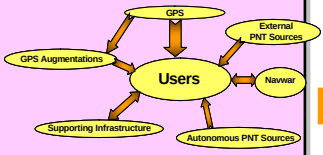
What can we do it with?

Trade Space Definition



How could we do it?

Concepts & Designs



What might they look like?

Design Evaluation

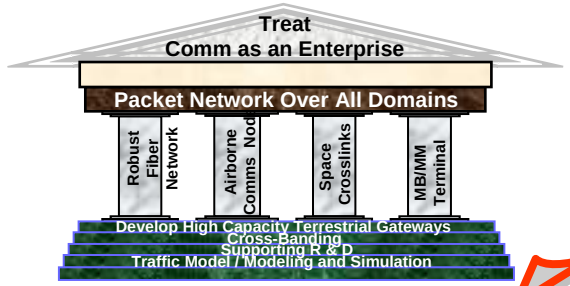
How well do they work, what do they cost, etc.?

Key Capability Identification

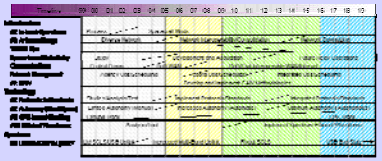
What have we learned?

Stakeholder Participation
Industry Input
User/Operator Input

Recommendations

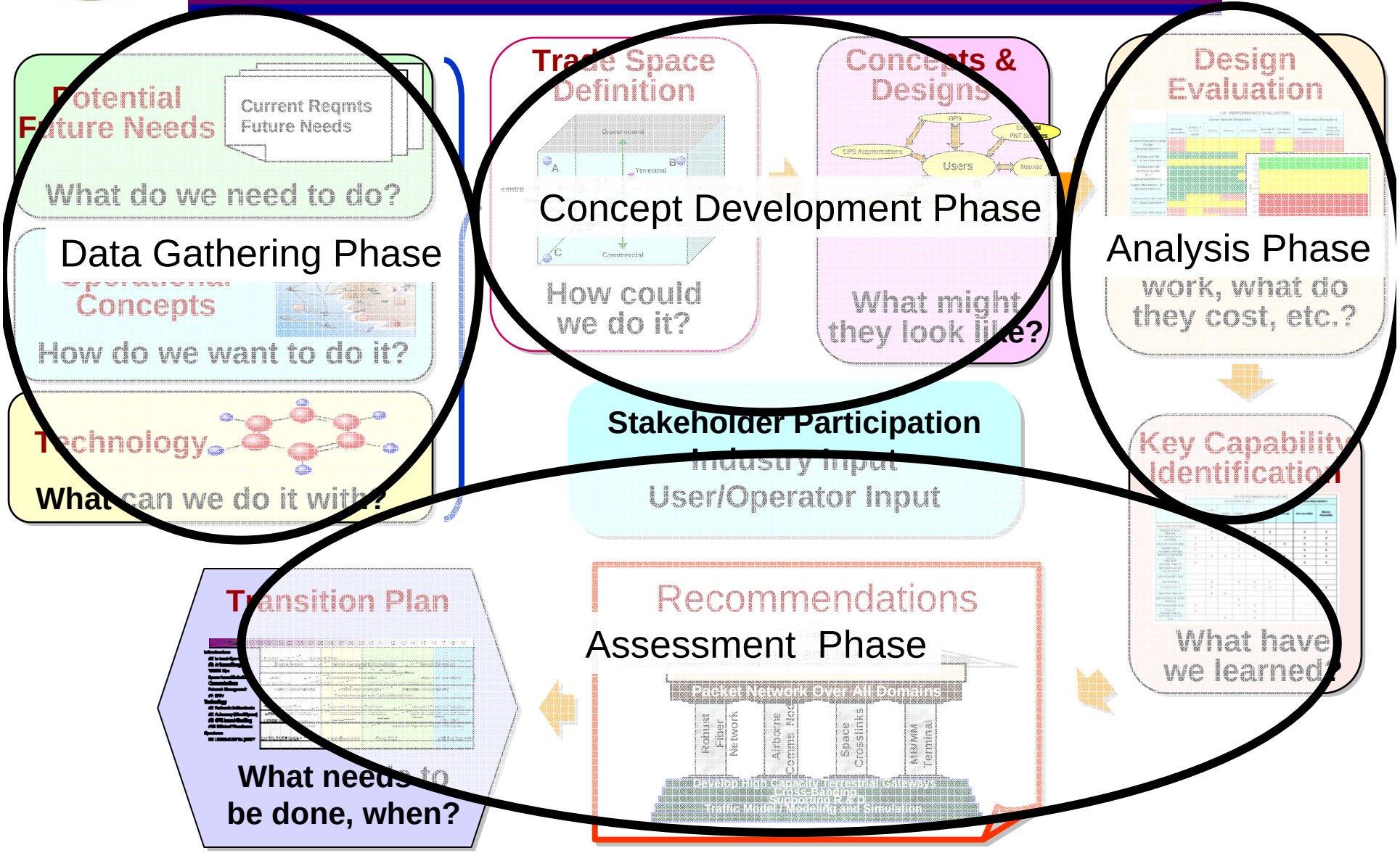


Transition Plan

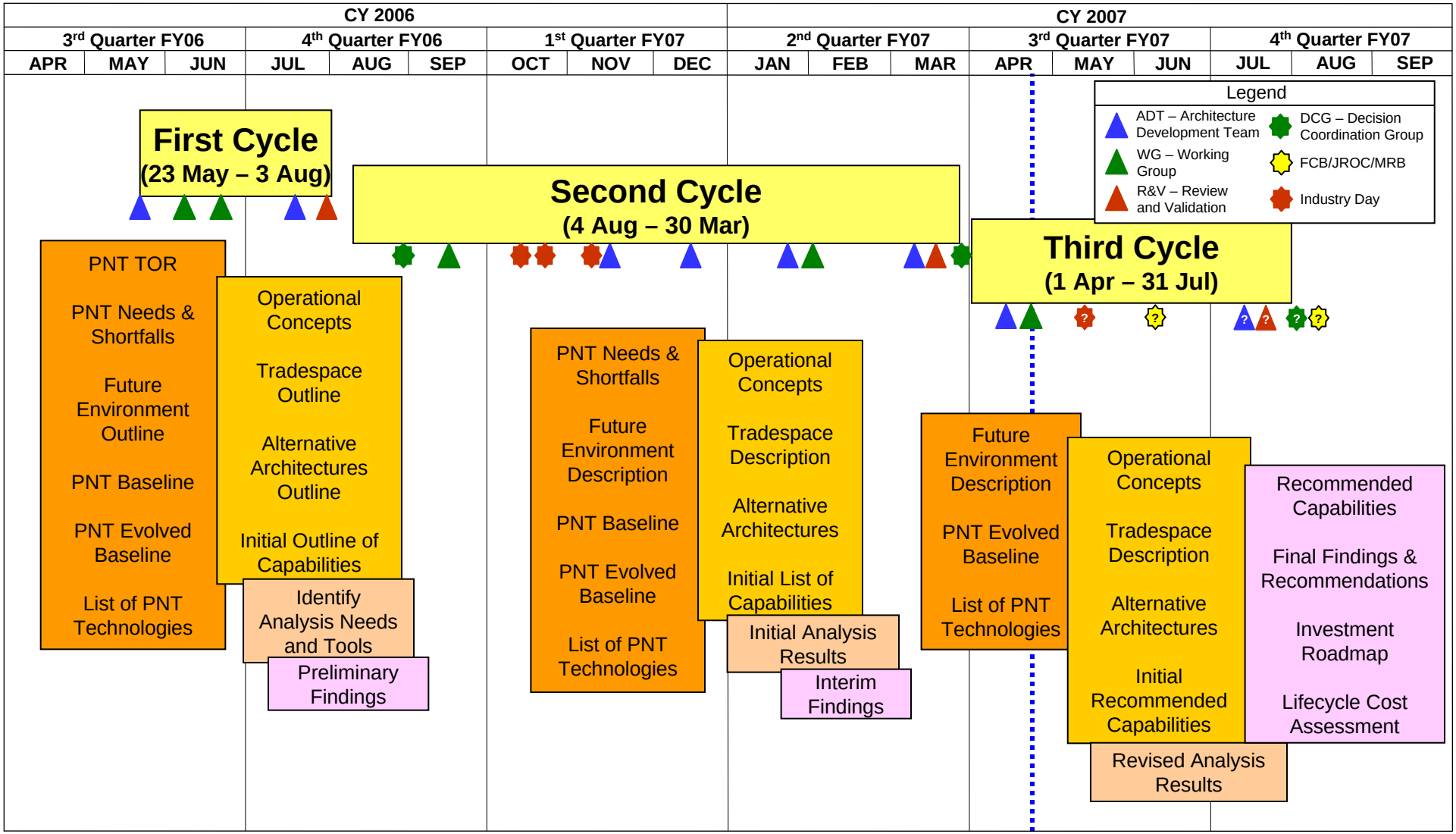


What needs to be done, when?

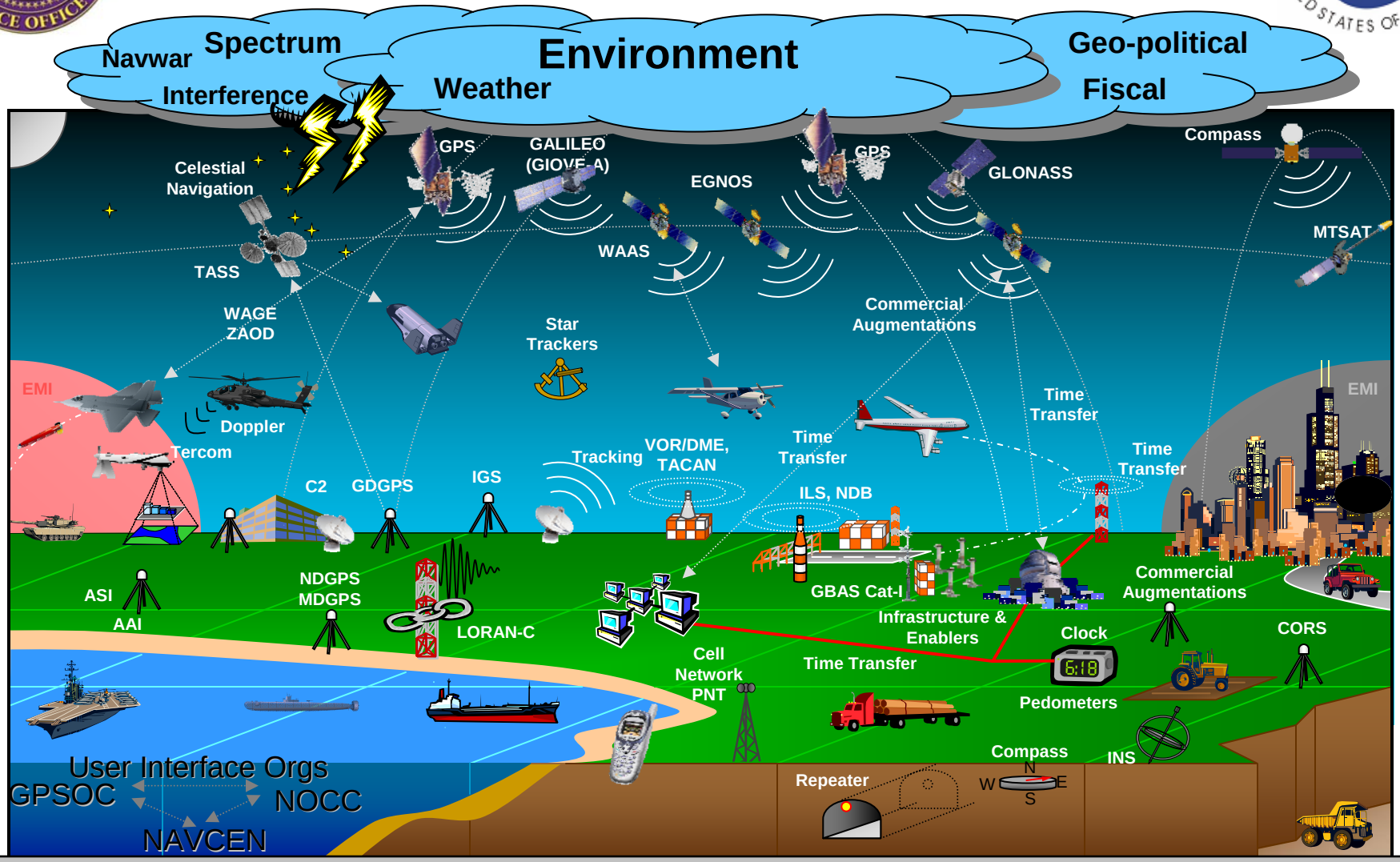
Architecting Process Overview



PNT Architecture Schedule



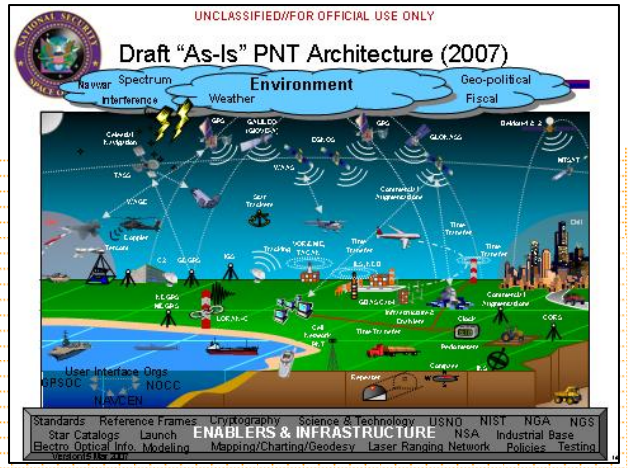
Draft "As-Is" PNT Architecture (2007)



Standards Reference Frames Cryptography Science & Technology USNO NIST NGA NGS
Star Catalogs Launch **ENABLERS & INFRASTRUCTURE** NSA Industrial Base
Electro Optical Info. Modeling Mapping/Charting/Geodesy Laser Ranging Network Policies Testing

Version16 Apr 2007

Evolved Baseline (EBL): 2007 - 2025



Capability

Based on Long Term Vision

"Should-Be" Architecture

Near and Mid Term Decisions Guided by Architecture

EBL

Without Enterprise Architecture Strategy

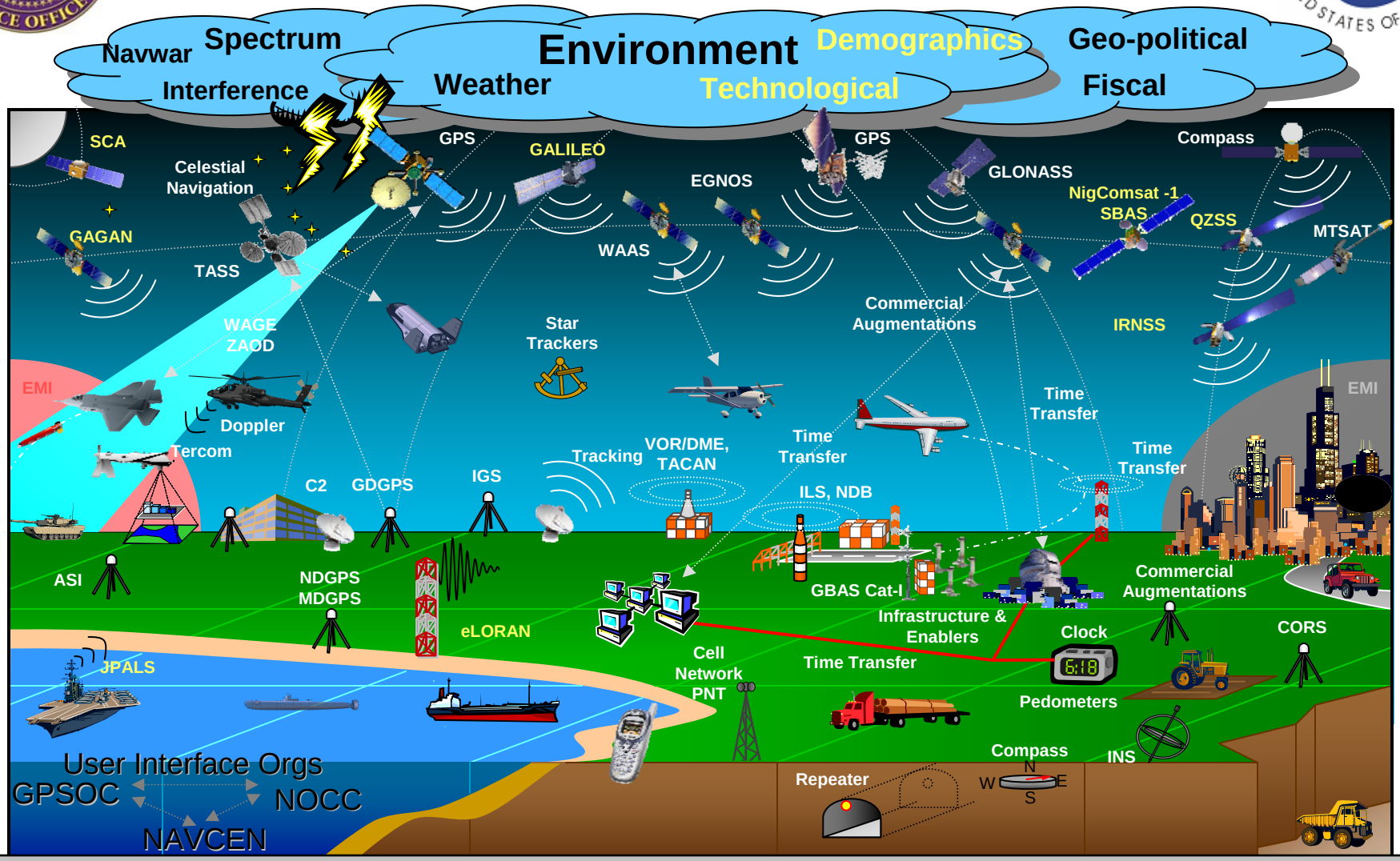
As-Is Architecture

System Emphasis

Architecture Emphasis

Now | 5 years | 10 years | 15 years | 20+ years

EBL (2025): How the future might look



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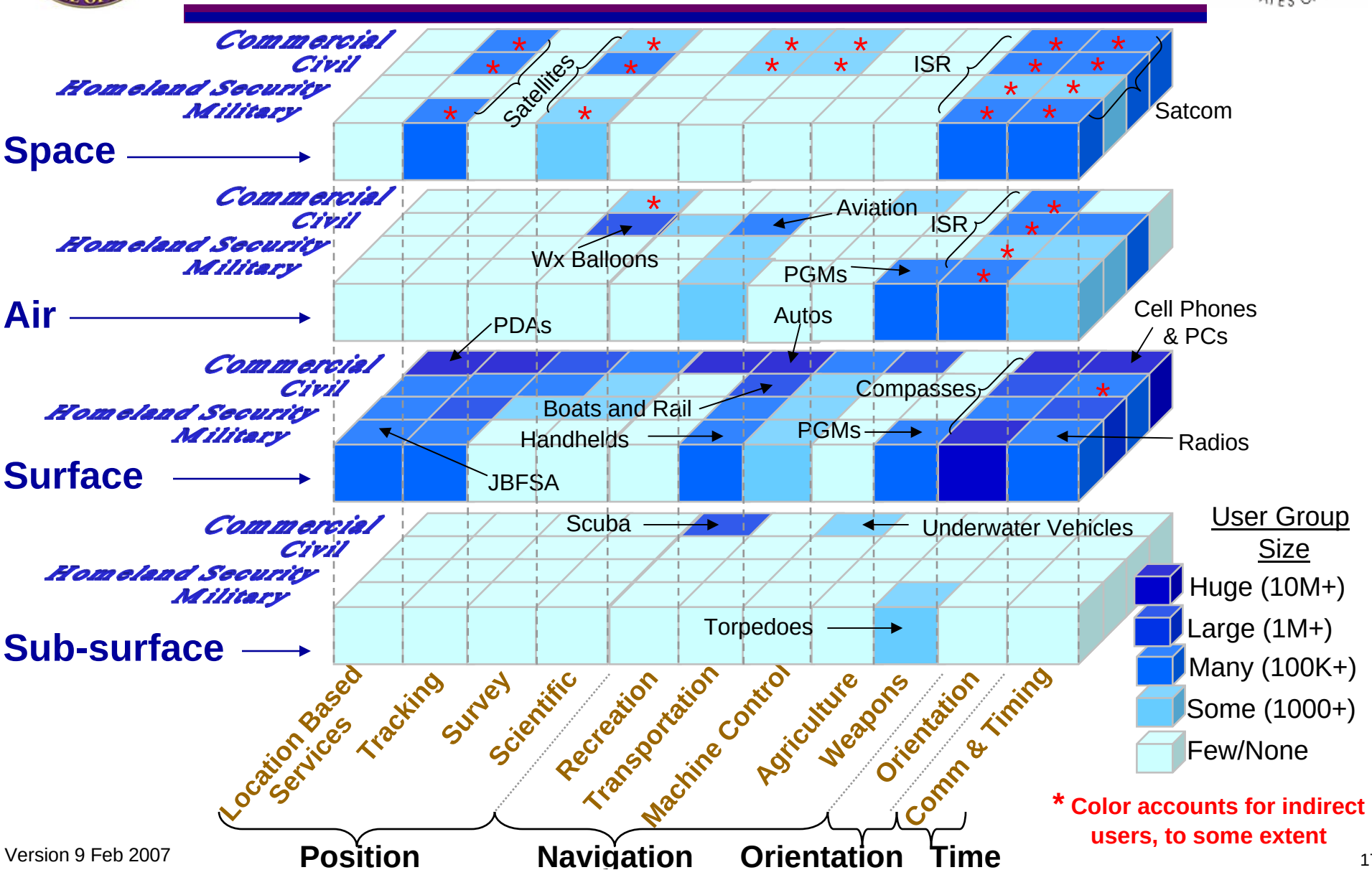
PNT User Perspectives (2025)



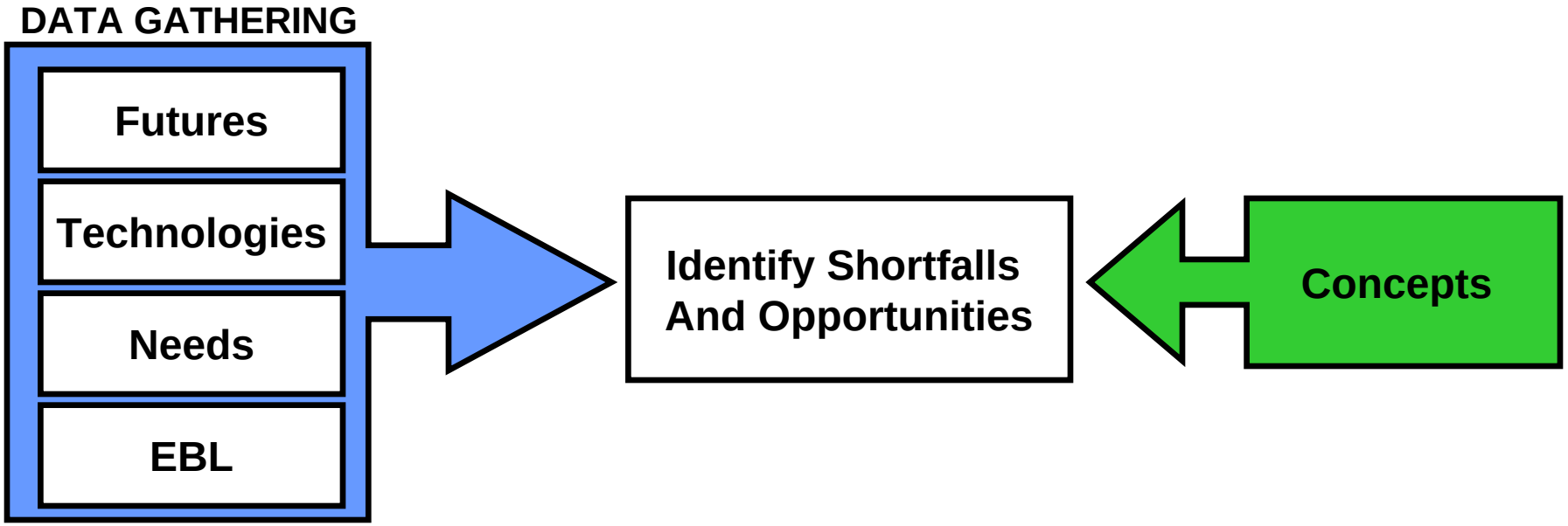
* Color accounts for indirect users, to some extent

Primary PNT Gaps

- Gaps primarily drawn from military's PNT Joint Capabilities Document, with additions and modifications from parallel civil community documents and discussions
  - Physically Impeded Environments
  - Electromagnetically Impeded Environments
  - Higher accuracy with integrity
  - Hazardously Misleading Info (Integrity)
  - High Altitude/Space Position and Orientation
  - Geospatial information - access to improved GIS data (regarding intended path of travel)
  - Insufficient modeling capability

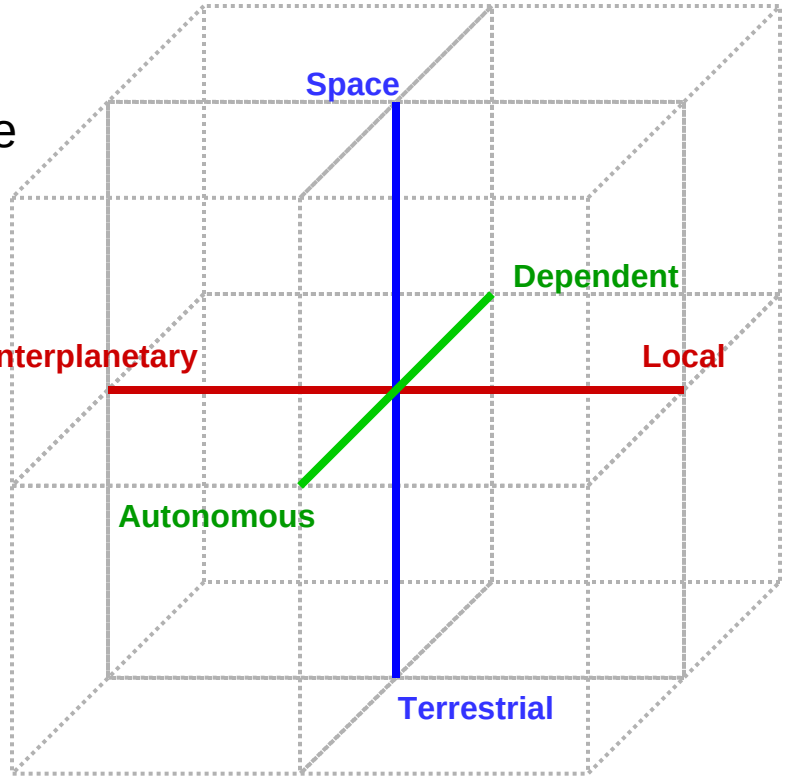
Concept Development Overview

- **Purpose**
  - Explore various concepts
  - Identify PNT capabilities
- **Concepts are first building blocks of the architecture**
  - Includes Policies, Institutions, Processes, Material

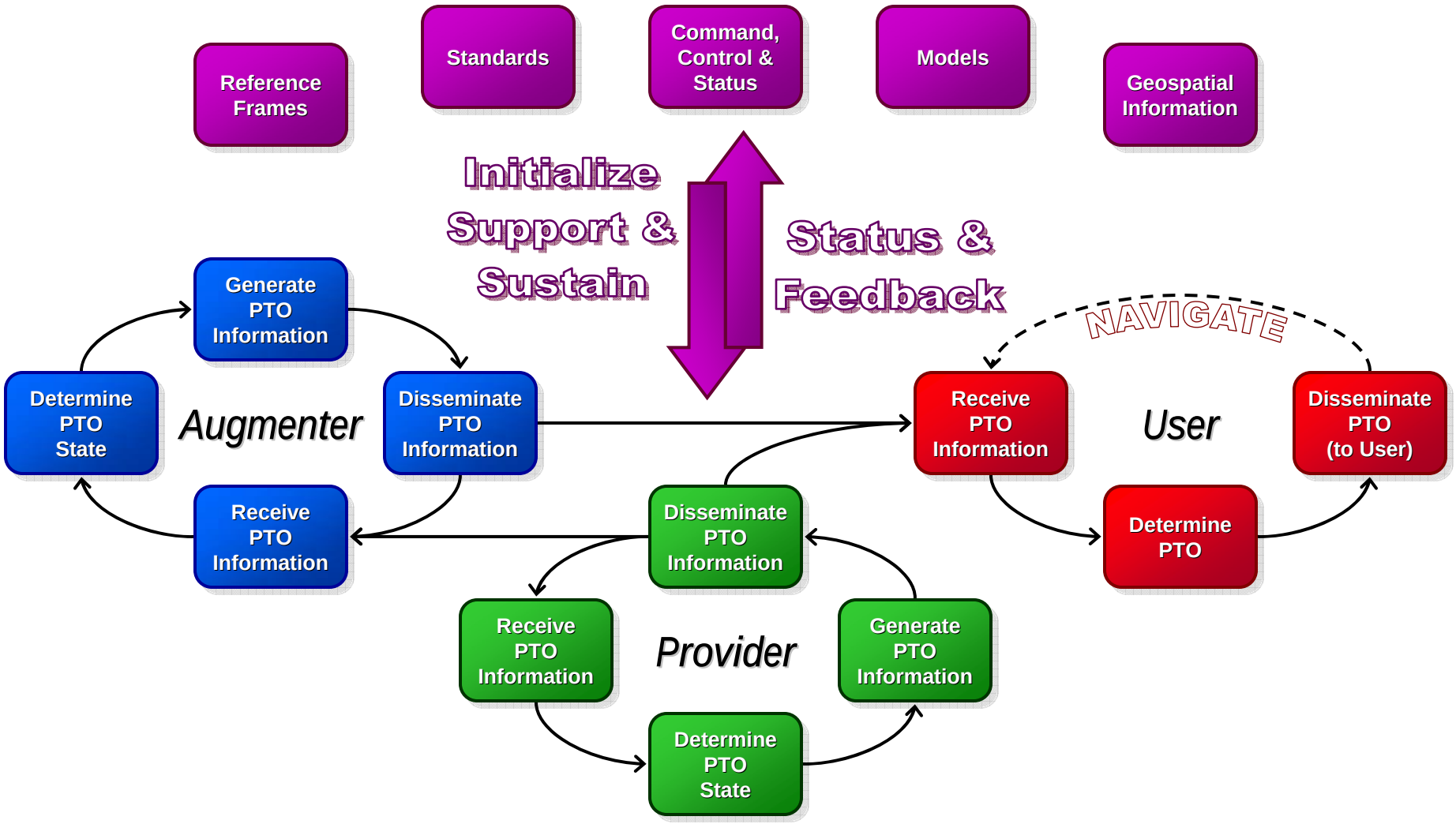


PNT Architecture Trade Space

- **Source Location** (of the service provider)
  - **Terrestrial**: concept provides service from, near, or beneath the surface of the earth
  - **Space**: concept provides service from space
- **Service Volume** (of the service provided)
  - **Local**: concept provides a meaningful service only at a fixed point
  - **Interplanetary**: concept provides a meaningful service throughout the solar system
- **Autonomy** (of the user)
  - **Dependent**: concept requires frequent refresh of information from external sources to provide a meaningful service
  - **Autonomous**: concept, once initialized, is self-contained and requires no refresh of information from external sources to provide a meaningful service



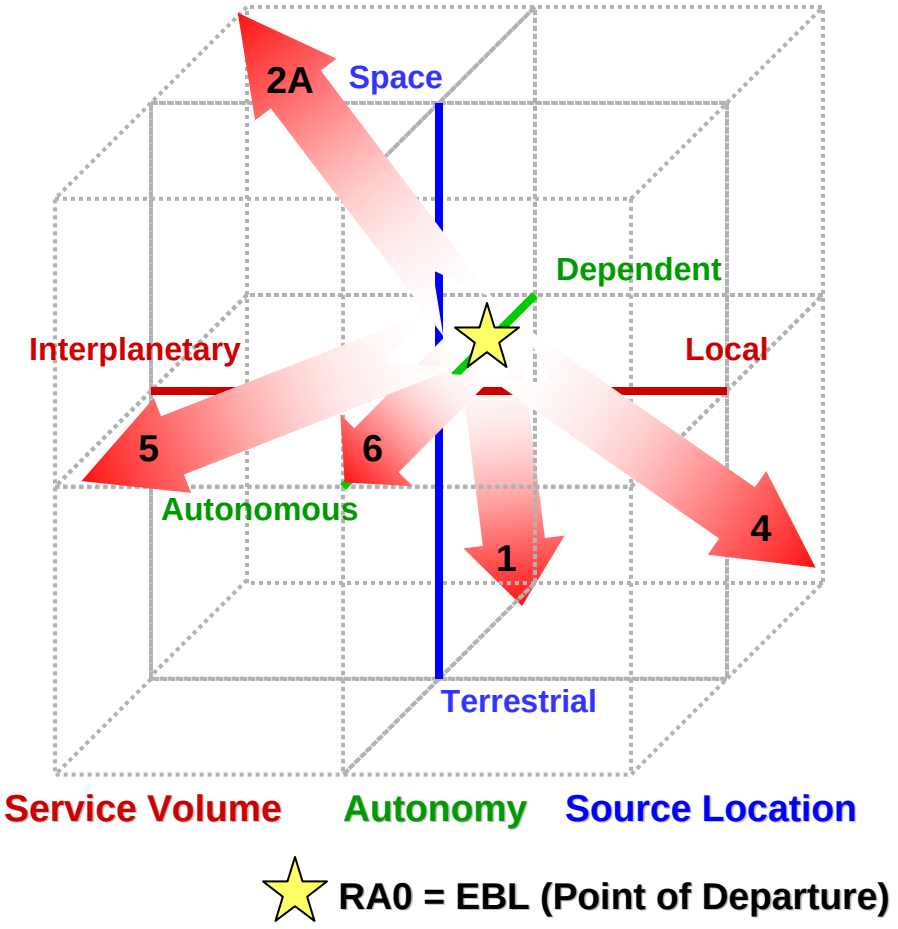
PNT Functional Reference Model



PTO: Position, Time, and/or Orientation

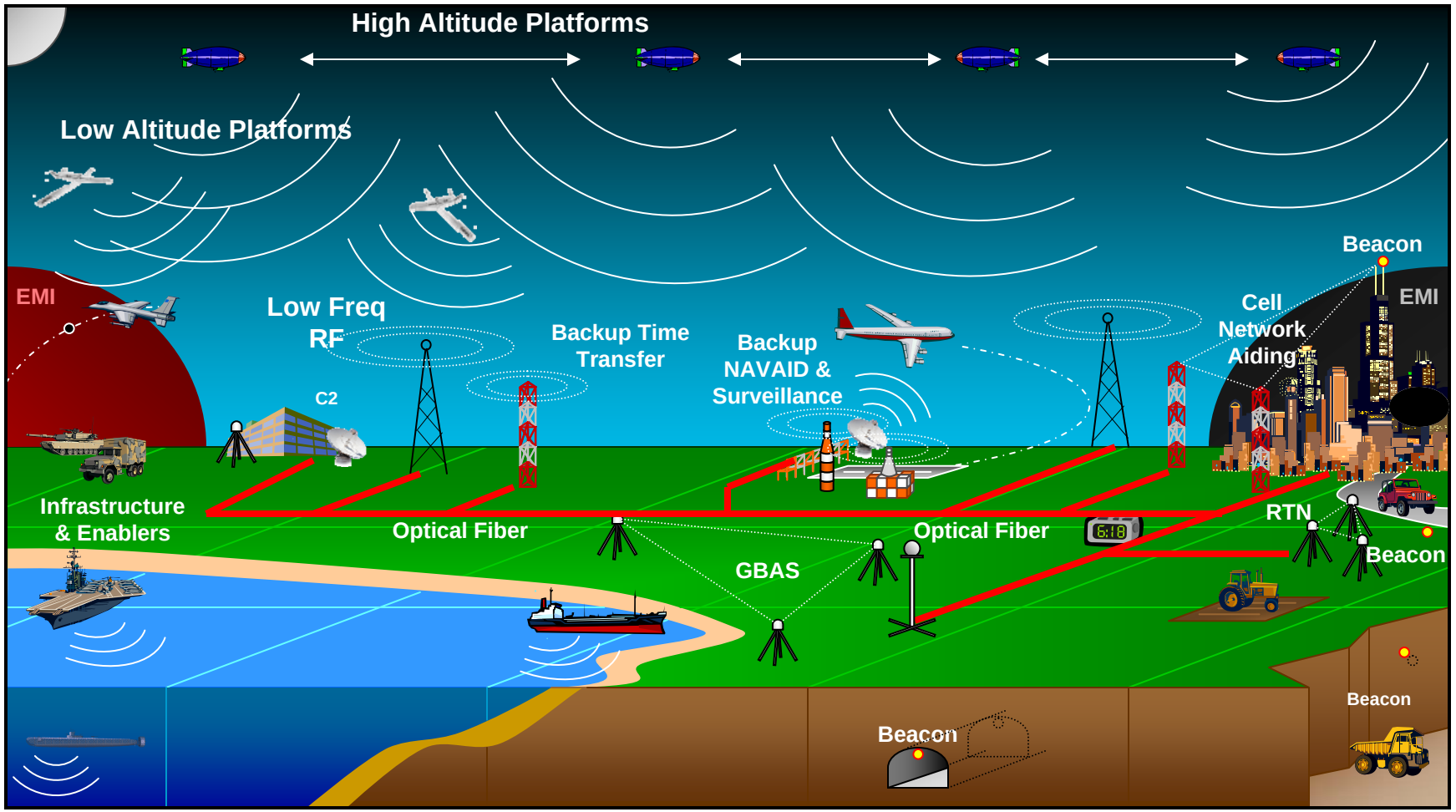
Representative Architectures (RA)

- 0: Evolved Baseline
- 1: Dependent Terrestrial
- 2A: Combined GNSS Constellations
- 4: Network Aiding of GNSS
- 5: Aided Autonomous Sensors and Aiding Sources
- 6: Highly Autonomous



RAs ARE *NOT* FINAL SOLUTIONS – THEY *ARE* USED TO GAIN INSIGHTS TOWARDS FINAL RECOMMENDATIONS

Example RA: Dependent Terrestrial



NOTE: DEPICTED ARCHITECTURE IS NOT A RECOMMENDATION

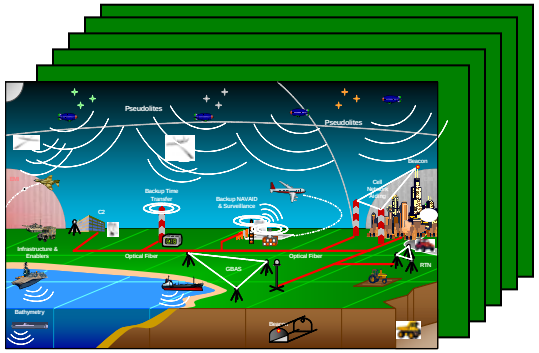
Preliminary Analysis

Needs
- Accuracy
- Availability
- Coverage
- Continuity
- Integrity
- Timeliness
- Security

Gaps
- Physically Impeded Environments
- Electromagnetically Impeded Environments
- Higher accuracy with integrity
- Hazardously Misleading Info (Integrity)
- High Altitude/Space Position/Orientation
- Geospatial information

Evaluators
- Adaptability
- Interoperability
- Robustness
- Sustainability

Risks
- Performance
- Programmatic
- Acceptance



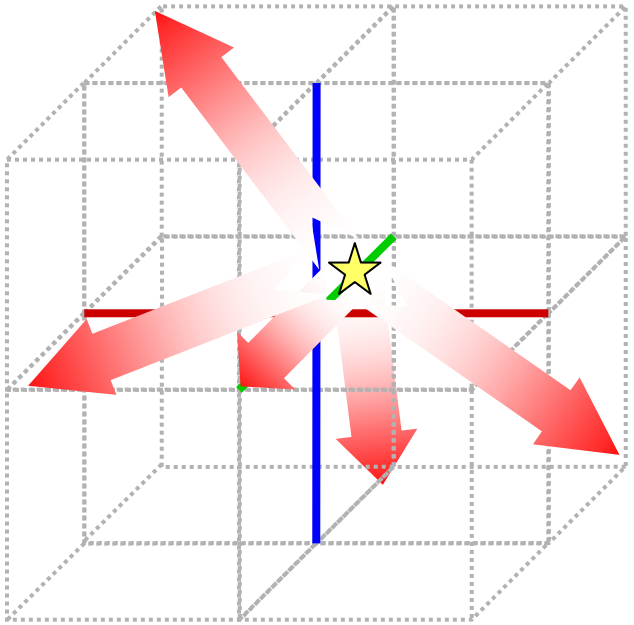
Representative Architectures

Stakeholder Scores and Comments (6000+) Reviewed and Consolidated to identify Insights and Key Features

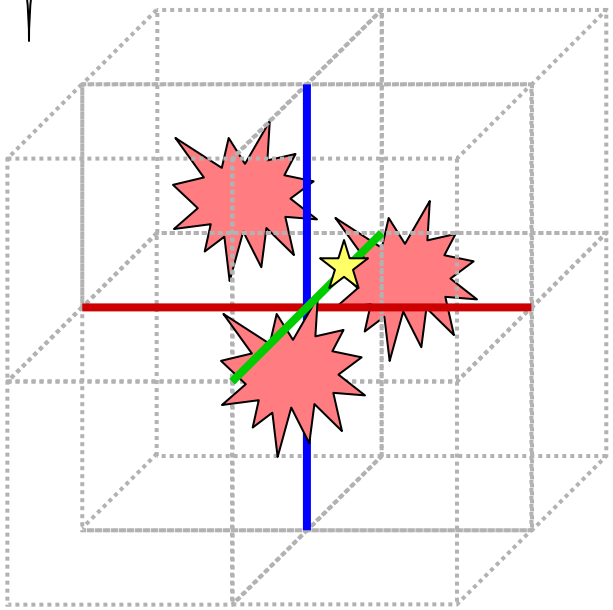
From Representative Architectures … to Recommendations

Preliminary Analysis (Feb - Mar 07)

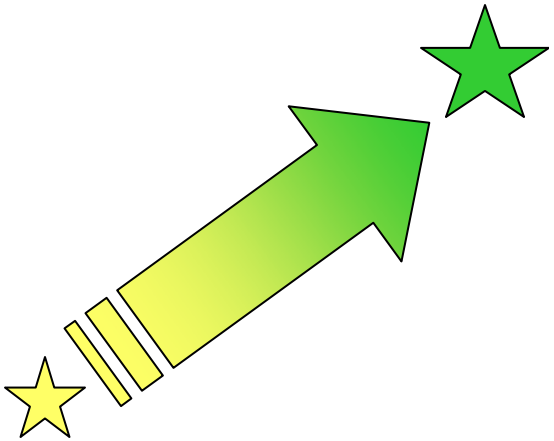
Cost and Performance Analysis (Apr - Jul 07)



Representative Architectures



Hybrid Architectures



Should Be Architecture

- **Recommendations**
- **Guidance**
- **Decision Criteria**

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Recap of Recent Activities

- Data Gathering (Aug – Nov 06)
  - Industry Days on east and west coasts
  - Review of civil needs (Volpe Center)
  - Presentation at Institute of Navigation Conference
  - Architecture Development Team (ADT) meetings in Aug and Nov
  - Products: As-Is and Evolved Baseline Architectures, PNT Gaps
- Concept Development (Nov 06 – Jan 07)
  - ADTs in Nov, Dec and Jan
  - Products: Concepts, Trade Space, Representative Architectures
- Analysis & Assessment (Feb – Mar 07)
  - ADTs in Feb and Mar
  - Products: Features, Insights, and Initial Findings
- Decision Coordination Group (Mar 07)
  - Approved way-ahead towards completion of effort

Preliminary Insights & Findings (1 of 3)

- US PNT Preeminence will face increased challenges at all levels
- Commercial PNT investments and services will increase significantly over the next 20 years
- PNT services will become more tightly integrated with other military missions as well as civil and commercial applications
- Demand for assured PNT in RF impeded environments (interference and obscuration) will increase
- Current GPS-centric architecture could be significantly altered by emergence of networked or autonomous PNT systems

Preliminary Insights & Findings (2 of 3)

- Signal diversity and use of multiple phenomenologies (autonomous, RF, networks, etc) are key to addressing identified gaps and providing robustness
- Higher power is one way to address impeded environment, but must consider implications of raising the noise floor
- Combined GNSS has the potential to provide improved accuracy and integrity; but the U.S. must maintain sufficient stand-alone global capability to support military operations
- Improvements to civil GPS performance and the advent of foreign PNT systems complicates Navigation Warfare, but can foster a cooperative international commercial environment

Preliminary Insights & Findings (3 of 3)

- Solution available for space/high altitude orientation gap—need improved star trackers and updated star catalogs
- Standards are an essential starting point for interoperability
- Low frequency RF-based systems are not sufficiently accurate to meet most-stressing positioning needs
- Political will may be needed if contemplating radical departures from the evolved baseline

Cycle 3 Products

- On track to deliver a Should Be Architecture for DCG approval in Jul 07
  - Recommended Capabilities
  - Supporting Findings
- Challenges
  - Sustain participation from stakeholder organizations
  - Using existing analysis tools to support long-term enterprise architecture decisions
  - Development and coordination of Implementation Plan
    - Targeted towards FY10 Budget Build Processes
  - Transition from “As Is” to “Should Be” Architecture
    - Requires Structured Approach for Implementation
    - Identify Responsible Agency Participants
    - Tie Programs and Plans to Architecture Recommendations
  - Sustaining the PNT Architecture as a configuration-managed baseline

Broad Scope Requires Innovative Approaches and Focused Analysis Efforts

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Architecture-level Questions

- How do we determine the line between government and user (or commercial) provided capabilities?
  - Economic impact
  - Safety of life
  - Critical infrastructure
- What PNT capabilities should be permitted/regulated by USG?
- What is the “right” mix of terrestrial, space-based, and autonomous sources … as well as government-provided global vs. regional augmentation systems? Commercial systems?
- What role should autonomous PNT capabilities play (ex: INS, clocks)?
- What is the future role of pseudolites and military augmentations?
- What requirements should be apportioned to basic GPS, which to augmentations, and which to user equipment?
- How can terrestrial/augmentation systems best make up GNSS shortfalls?

Architecture-level Questions

- How important is our leadership role in providing global PNT?
- What PNT services are most appropriate to support critical infrastructure?
- Can existing infrastructure (commercial fiber, established stations, etc) be reused or leveraged to support PNT?
- Is DoD too dependent/reliant on GPS as a primary PNT source?
- Should the US continue to pursue exclusive military services or instead assume availability of PNT to all on the battlefield?
- What role should foreign navigation services play in providing PNT capabilities?
  - Does DoD continue to use only US PNT services?
  - Should WAAS and NDGPS monitor and broadcast Galileo corrections?
- What international principles, policies, agreements, and cooperation are most important in protecting US national security and the US economy?

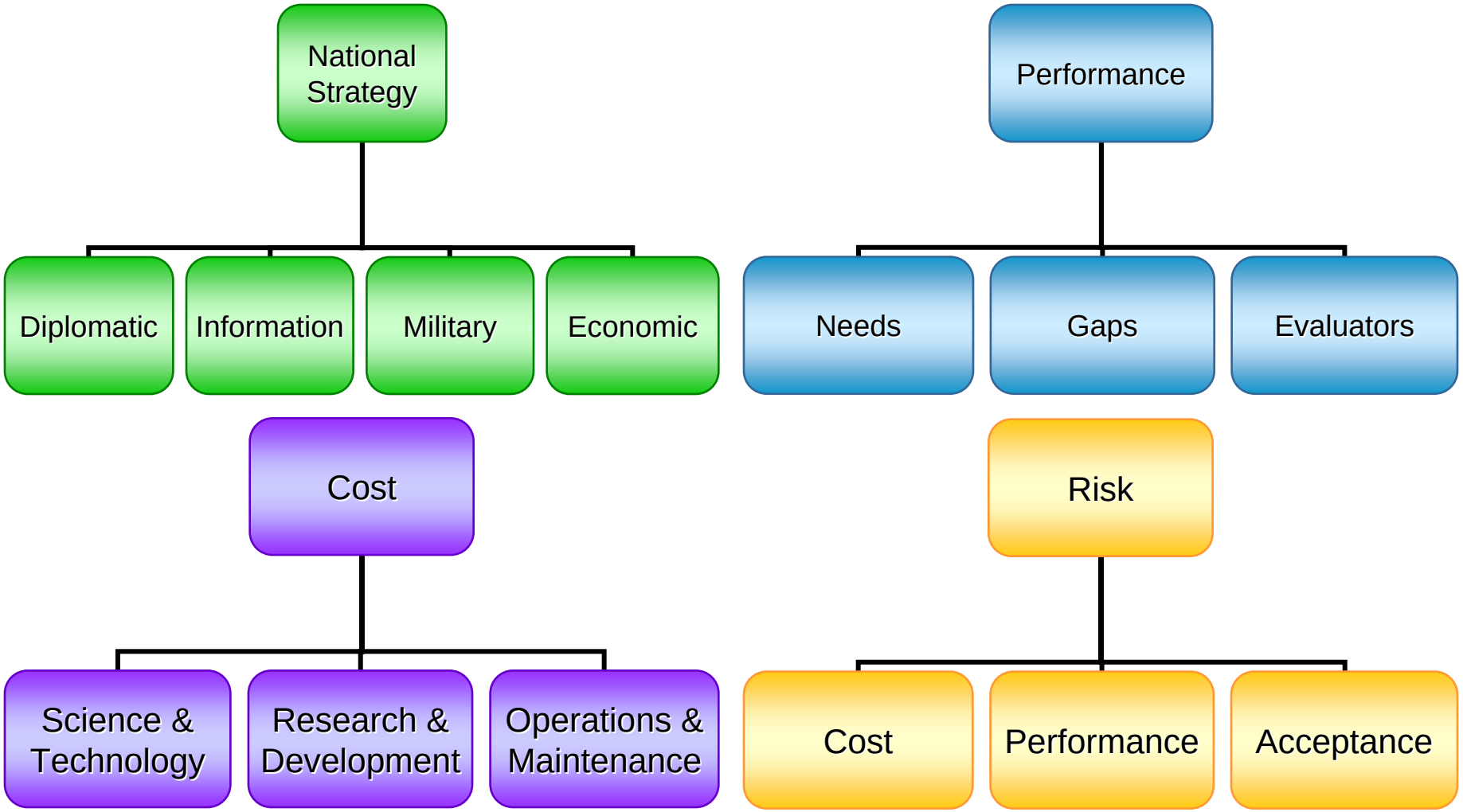
Architecture-level Questions

- Funding priorities: Which PNT capabilities should we field next? Who pays: service provider vs. user?
- Where should we look first if we have to make cuts?
- Within Federal Government, which agency funds a program with overlapping requirements?
- How can we meet long-term PNT and orientation needs for high altitude and space users?
  - Can these PNT capabilities be leveraged to provide capability beyond geosynchronous orbit?
- How should we synchronize space, control, and user segments?
- What capabilities and coordination should be planned in order to control and operate the systems in the PNT Architecture?
- What architectures or components help avoid or mitigate electromagnetic interference?

Architecture-level Questions

- What PNT backup systems are required? (Especially for critical infrastructure)
- How can we better embrace commercial industry and academia, since they are often a driving force for innovation and change?
- How do we protect the spectrum, nationally and internationally?
- How will the FAA study on future of WAAS and GBAS impact the architecture?
- What are the implications of Net-Centric PNT?
- How will software defined radios impact the future of PNT?

Strawman Analytical Framework



INCLUDES QUALITATIVE AND QUANTITATIVE MEASURES

Overview of Civil PNT Challenges

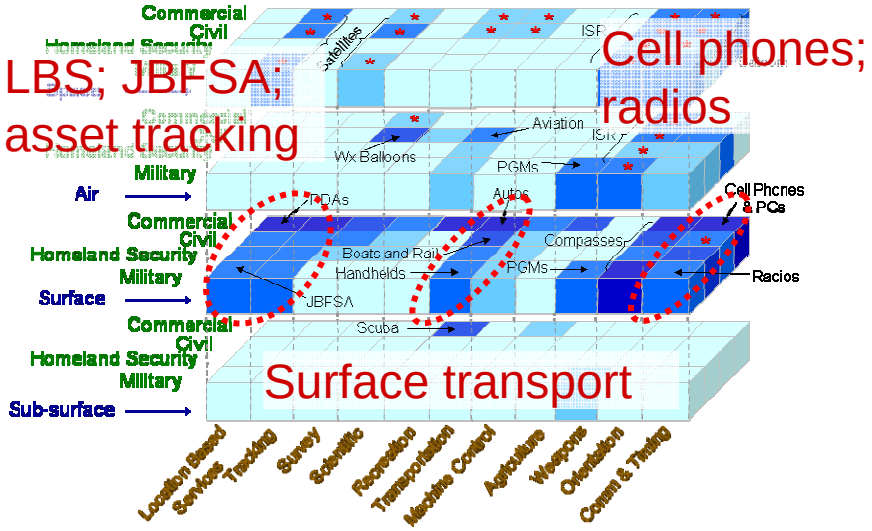
- Diverse Set of Applications with Different Performance Requirements
- No Overarching Strategy Documents to Define Civil GPS/PNT Requirements – Identified in Civil PNT Analysis of Alternatives Study
- Promulgation of GPS Augmentation Systems
- What is the “Right” Mix of Terrestrial, Space, Based of Autonomous NavAids to Meet Performance Requirements?
- What is the “Right” Mix of Government-Provided GPS Augmentation Systems? Commercial Systems?
- Within Federal Government, Which Agency Funds a Program with Overlapping Requirements?

Primary PNT Gaps

- Gaps primarily drawn from military's PNT Joint Capabilities Document, with additions and modifications from parallel civil community documents and discussions
  - Physically Impeded Environments
  - Electromagnetically Impeded Environments
  - Higher accuracy with integrity
  - Hazardously Misleading Info (Integrity)
  - High Altitude/Space Position and Orientation
  - Geospatial information - access to improved GIS data (regarding intended path of travel)
  - Insufficient modeling capability

Gap: Physically Impeded Environments

Who: Cell phones, radios, PDAs for LBS, and asset tracking, surface transport



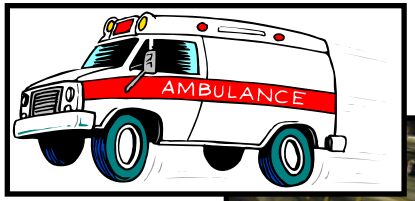
Why: Growth of urban areas; growing indoor applications; current GPS radio frequency signals not always available

What: Assured and real time PNT in physically impeded environments

Where: Areas including indoors, urban canyons, underground, underwater, and under dense foliage; users moving at surface speeds; communications available

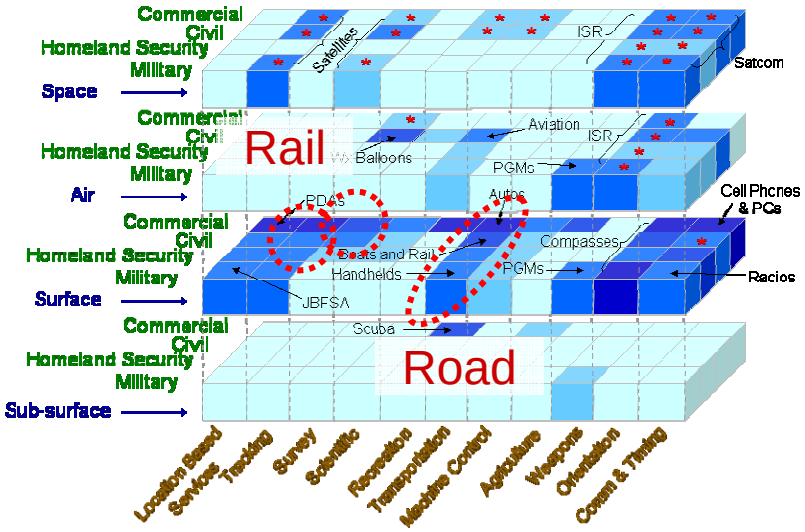
Issues: Cost a key constraint; multipath; user equipment size/weight

Reference: PNT JCD



Gap: Higher Accuracy with Integrity

Who: Future automobiles; railroads



Why: Growing population requires increased road and rail capacity; allows more cars/trains to safely fit on the same highways/tracks; increased efficiency/profits; improve safety

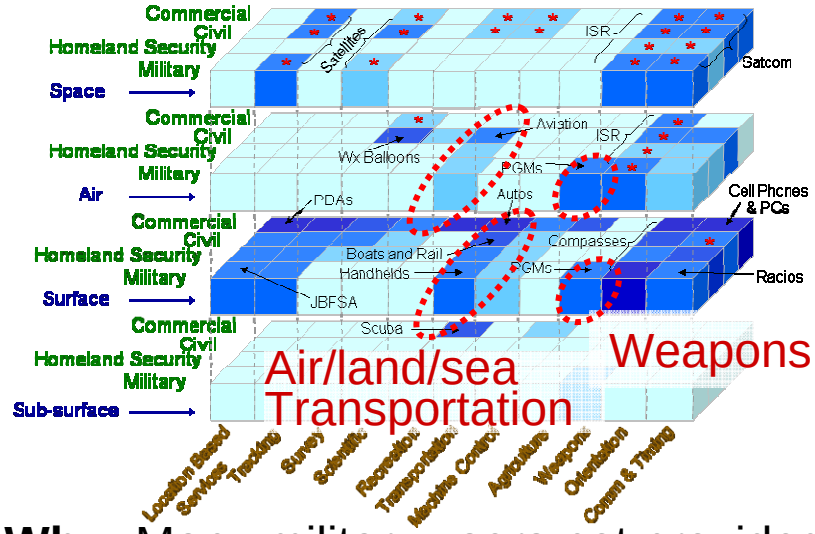
What: Advanced driver assistance (road departure and lane change collision avoidance) systems need 10cm accuracy; railroads need 1m accuracy for positive train control and 10cm accuracy for rail survey and test; advisory systems affecting safety of life drive integrity requirements

Where: On roads/rail at surface speeds; includes urban canyons, under canopy, in tunnels & valleys

Reference: 2006 FRP and PNT JCD

Gap: Notification of Degraded or Misleading Information (Integrity)

Who: Air and surface transportation; weapons



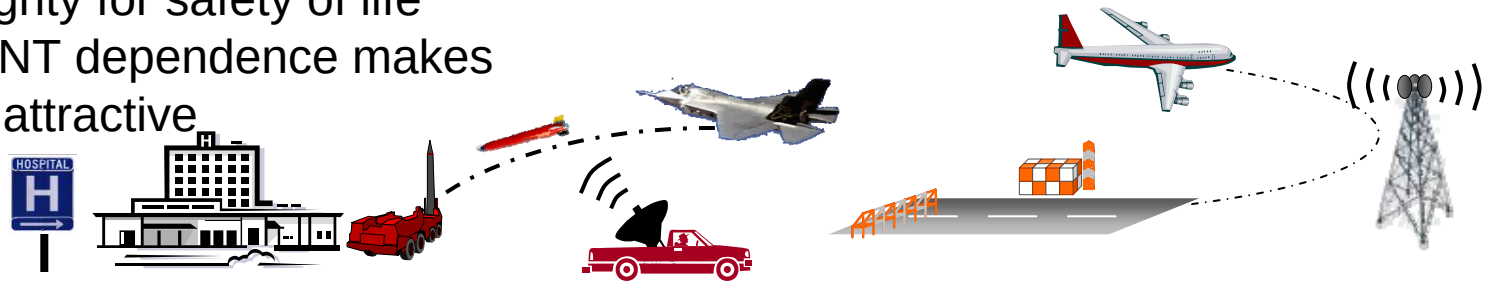
Why: Many military users not provided with timely notification of degraded or misleading info; civil community seeks lower cost integrity for safety of life applications; PNT dependence makes spoofing more attractive

What: Timely notification (as short as 1 sec in some situations) when PNT information is degraded or misleading, especially for safety of life applications or to avoid collateral damage

Where: Transportation routes including roads, harbors, & airport approaches; military ops especially with high jamming/spoofing threat

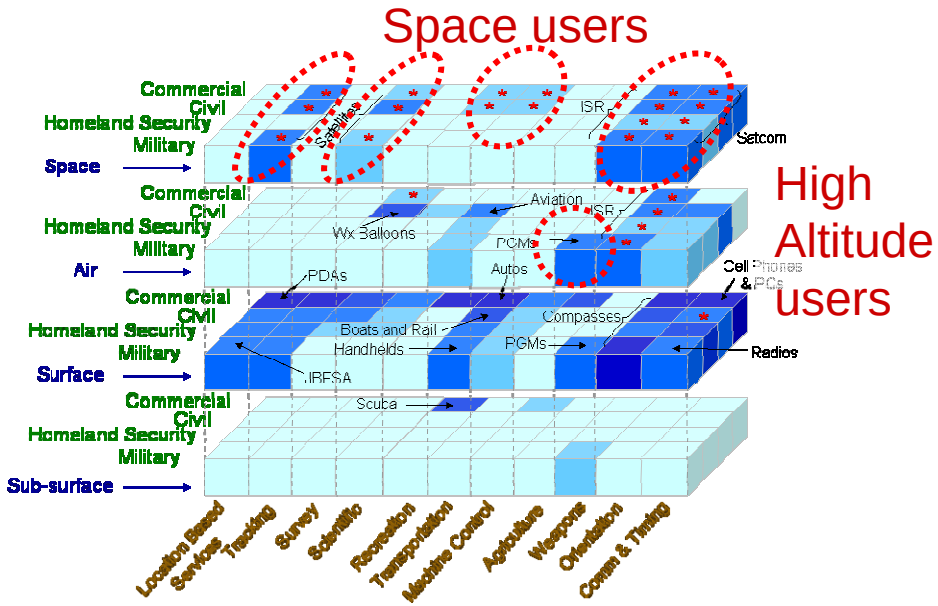
Issues: Integrity requirements for JBFSA and intelligent highway use; sufficient availability of integrity

Reference: PNT JCD



Gap: High Altitude/Space Position and Orientation

Who: Support to "space situational awareness, intelligence collection, and other missions"; NASA missions



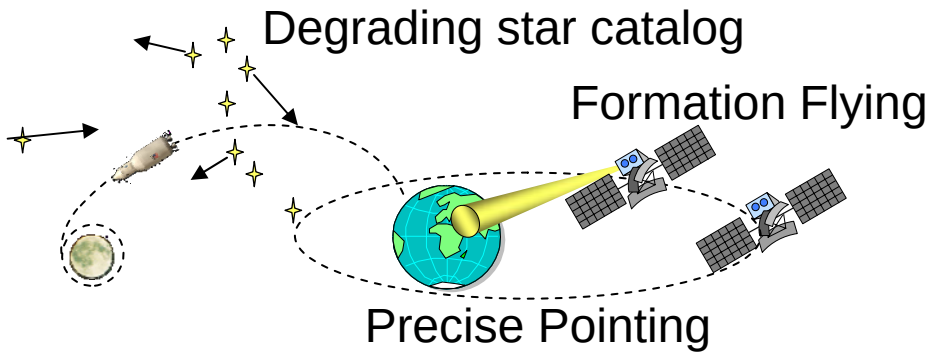
Why: Current star catalog degrading; growing scientific uses—formation flying; navigation in environments with sparse radiometric signals

What: Real time high accuracy position and orientation (<10 milliarcseconds) information. Example: 3cm (relative) formation flying

Where: Space (Keplerian orbits) and at high altitude (medium dynamics)

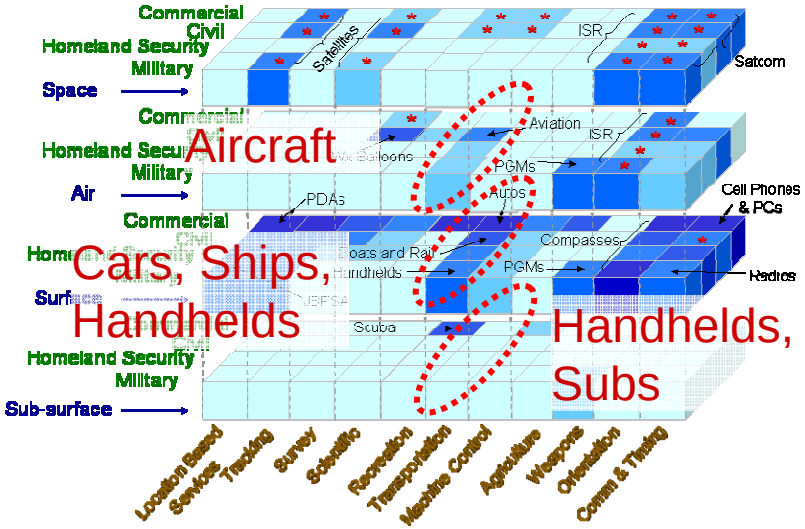
Issues: No funding to update star catalog; GPS signal availability at GEO and beyond; need for additional radiometric sources beyond Earth orbit (cislunar space, and beyond)

Reference: PNT JCD; NASA Space Communication (and Navigation) Architecture



Gap: Geospatial Information

Who: Air, surface and subsurface navigation users



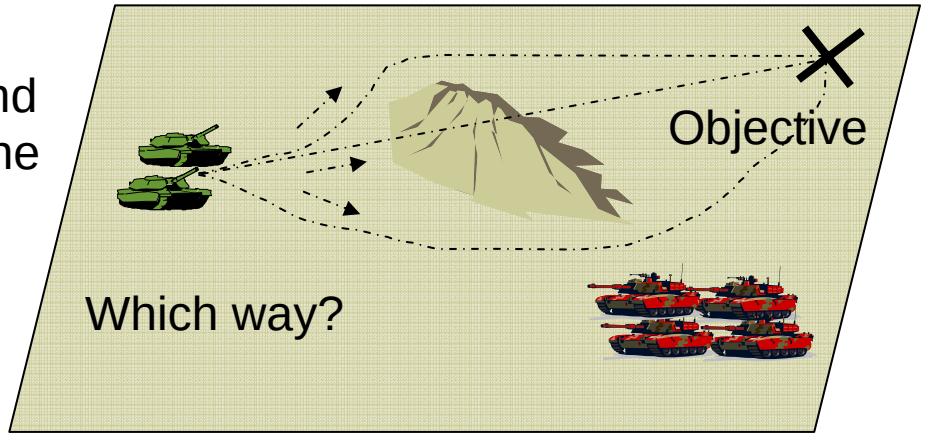
Why: Robust geospatial information facilitates use of navigation information and provides the user with the knowledge of the environment along the intended path of travel.

What: Users require access to timely geospatial information for successful navigation

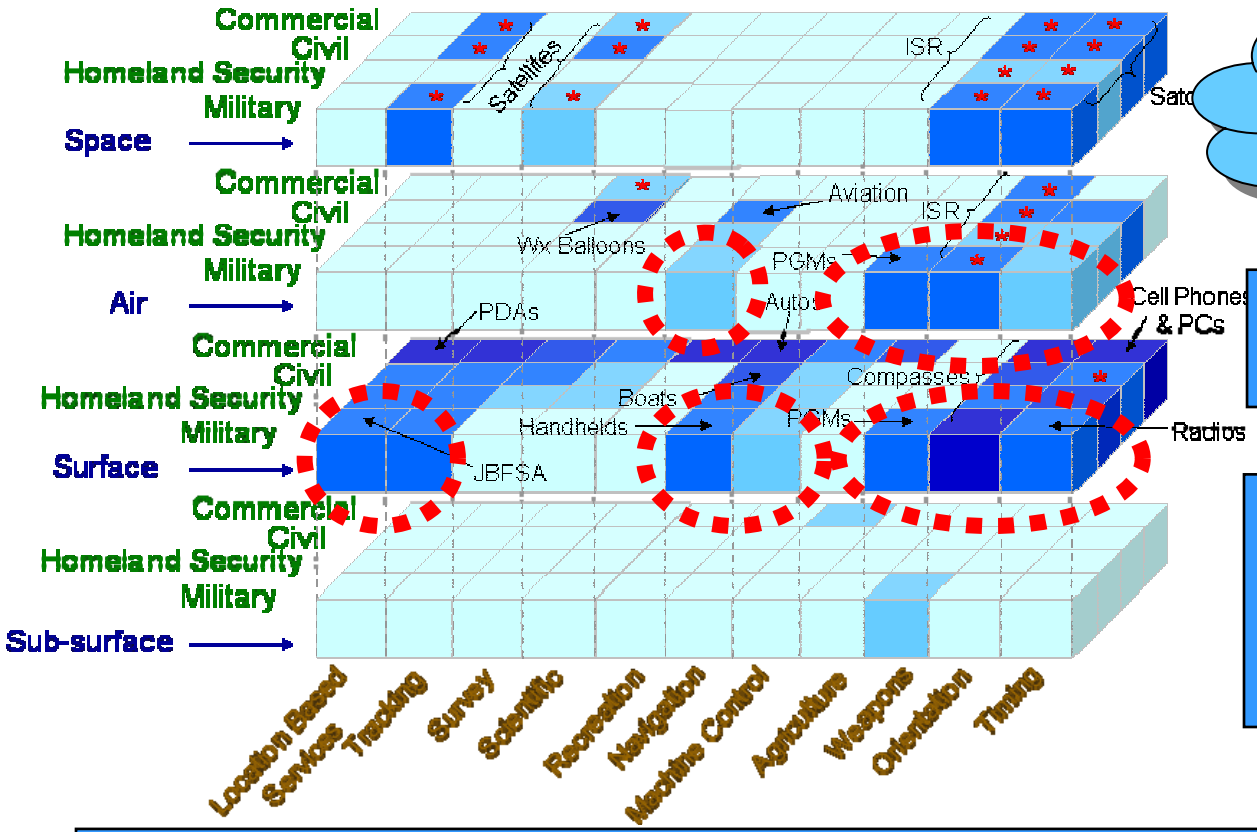
Where: On, near, or under the surface of the earth

Issues: What information is needed? How should it be produced? How should it be disseminated? How should it be processed, fused, and displayed?

Reference: PNT JCD



Gap: Insufficient Modeling Capability



Growing jamming threat; interference more common

Characteristics:
- Primarily a DoD need

Now used: GIANT; SBMCS; Nav Tool Kit; reach back to GPS Ops Center, JSOC, JNWC

Need: Capability to model PNT capabilities in impeded conditions to determine impacts; need more timely capabilities; capability to predict impacts in urban environments

Key Users: Joint mission planners

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